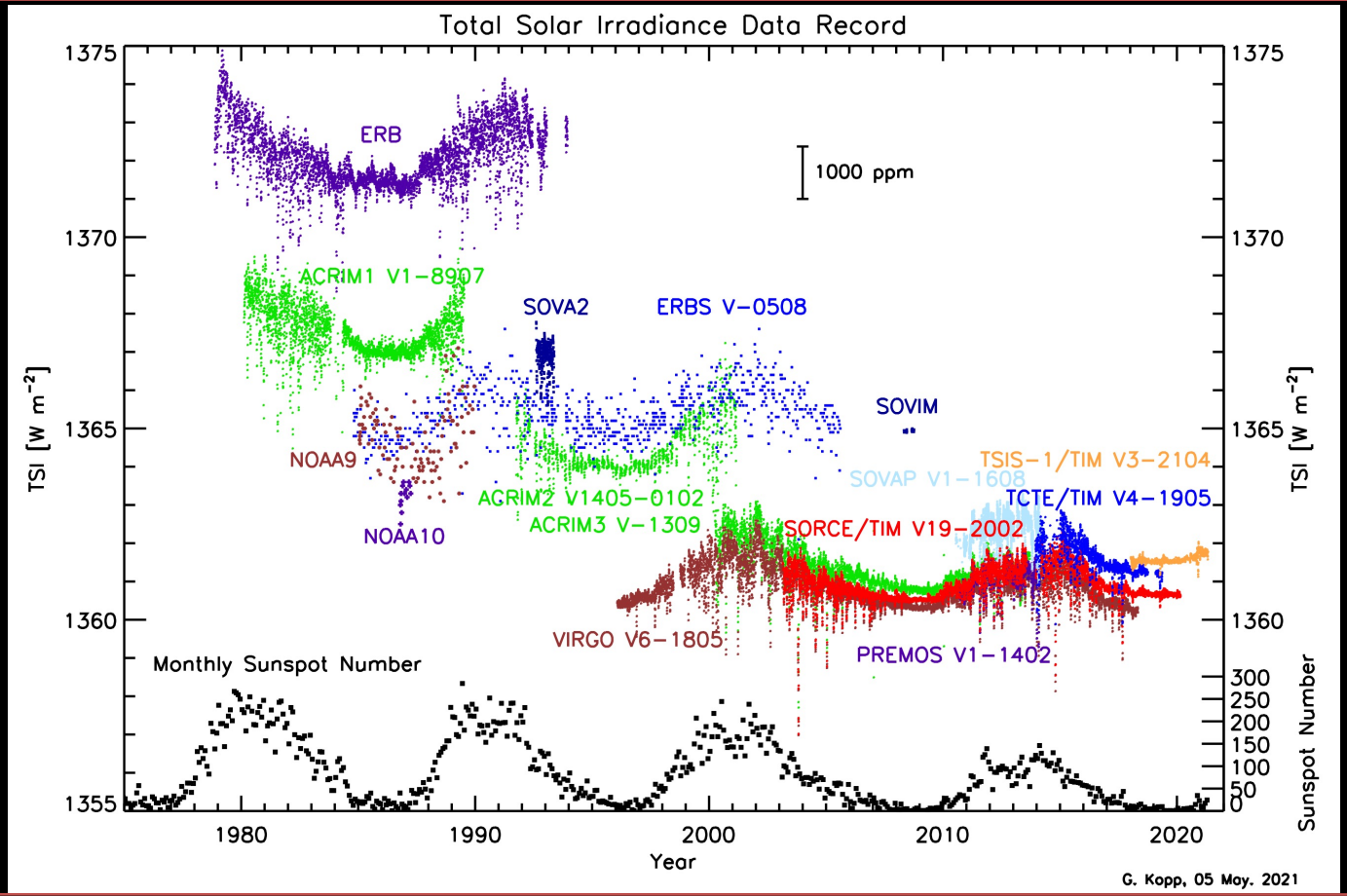
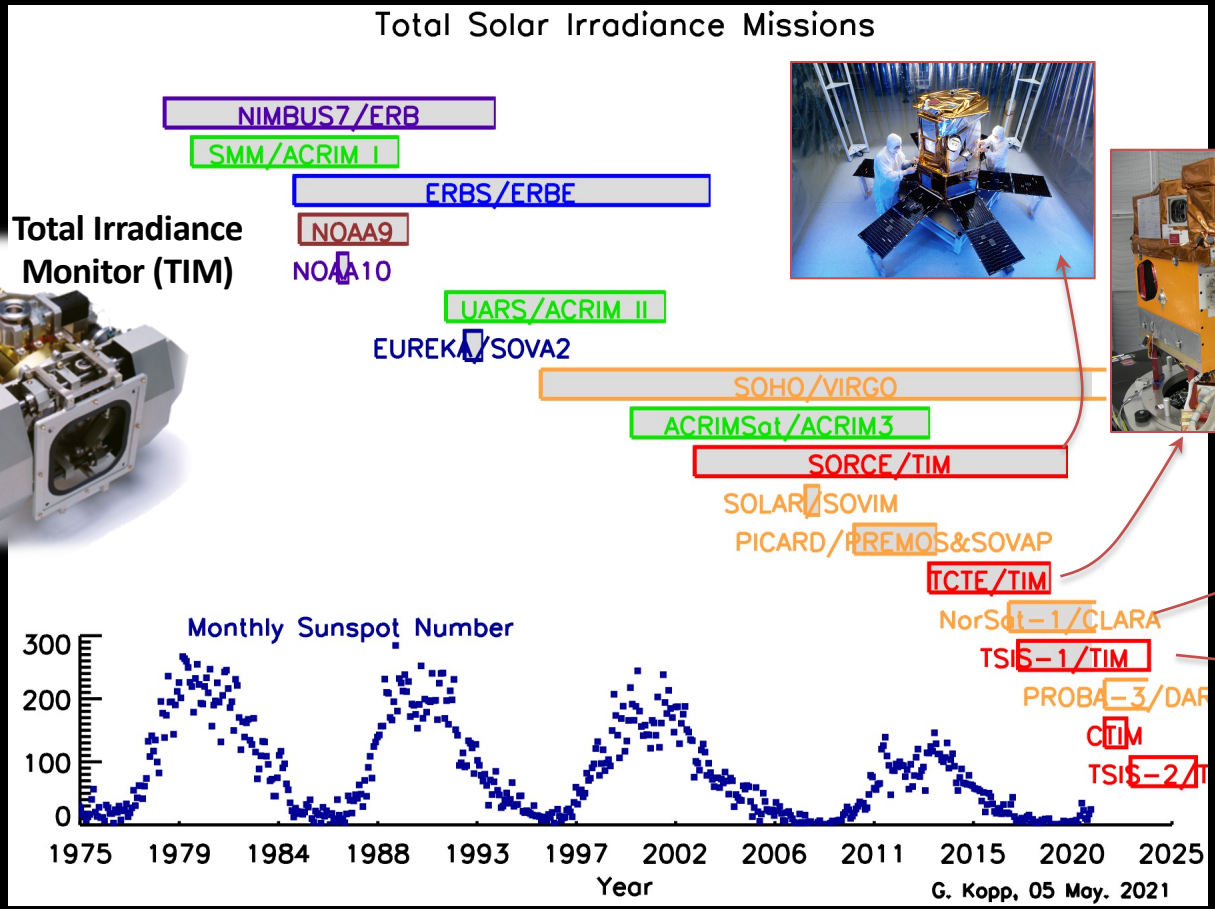
Why Can't We All Just ...
The 'Community- Consensus TSI Composite'

Greg Kopp, Thierry Dudok de Wit, Will Ball, Wolfgang Finsterle, Claus Fröhlich, Sabri Mekaoui, Werner Schmutz

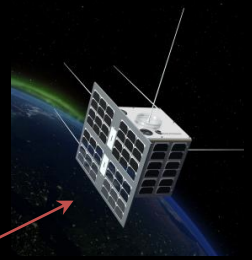
Energy Balance and Climate Studies Depend on Total Solar Irradiance

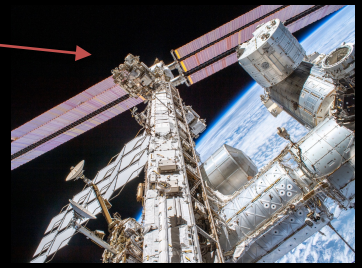


TSI Missions

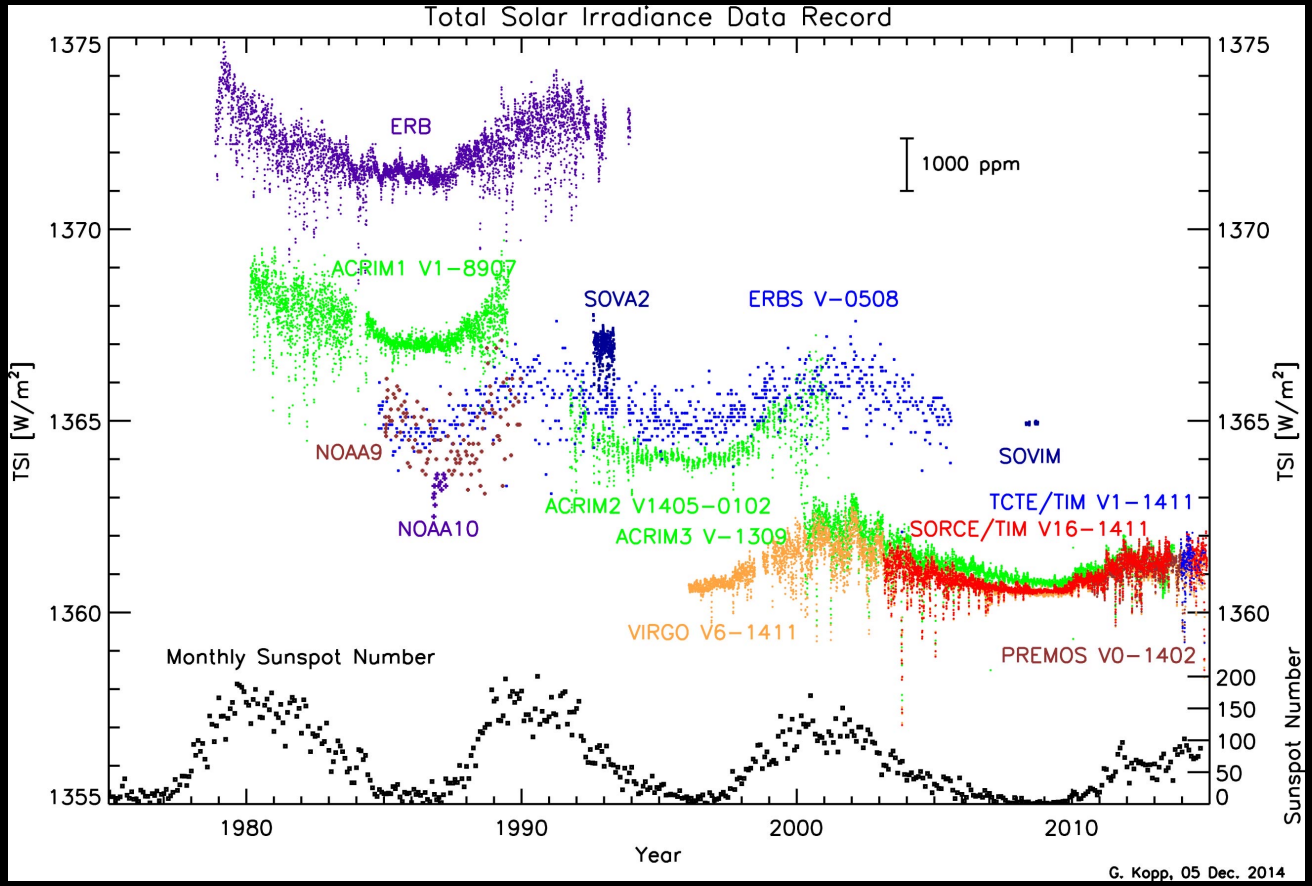


Total Irradiance Monitor (TIM)

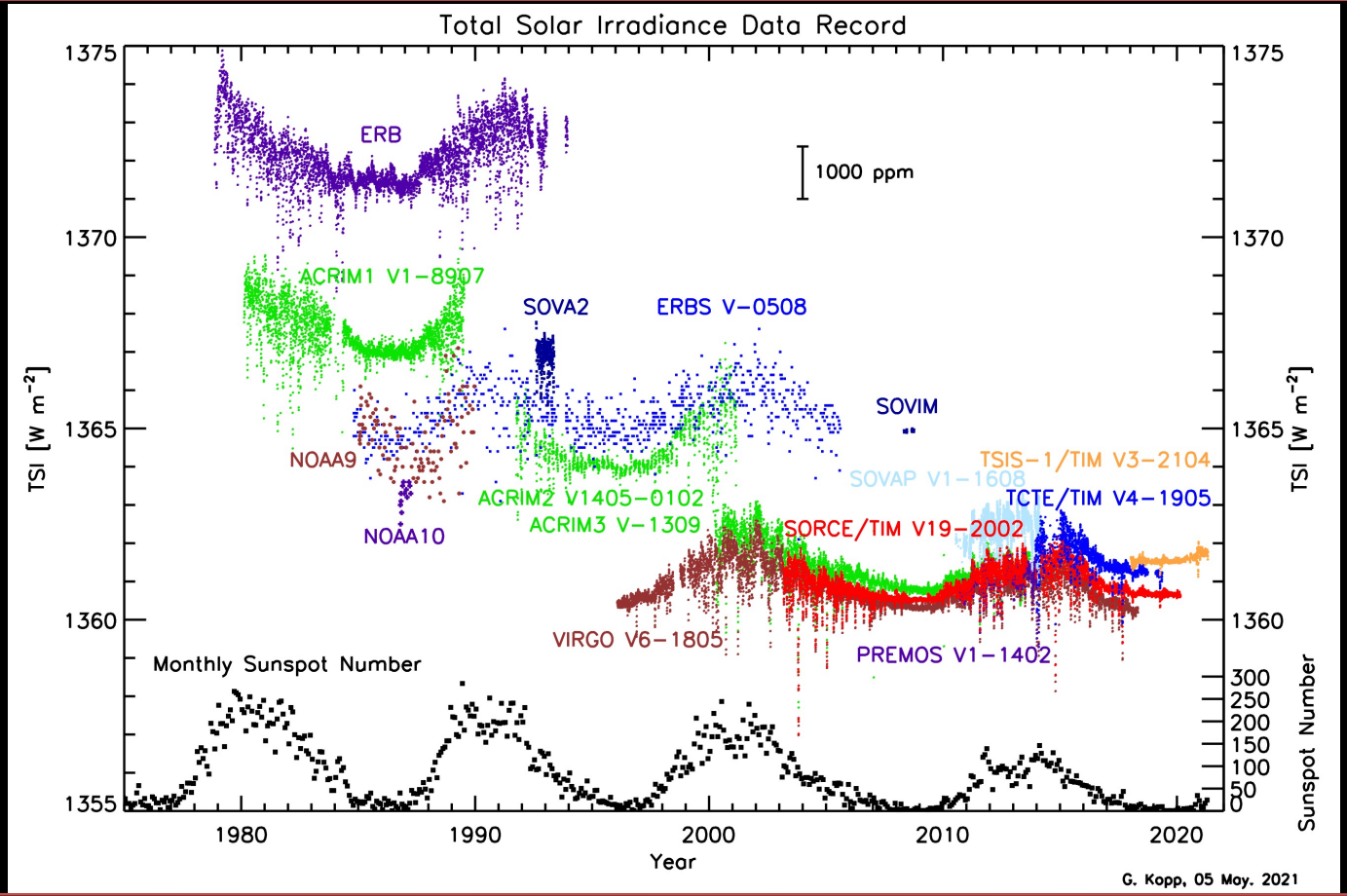




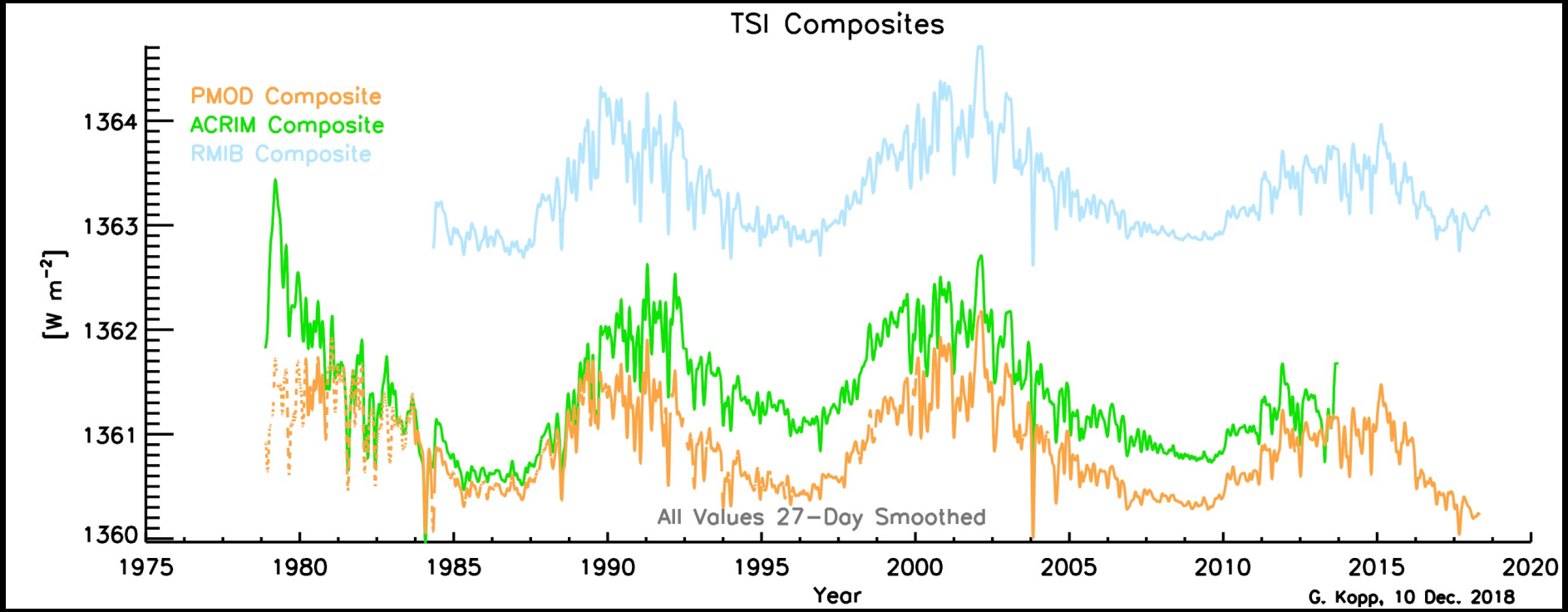
“Recent” Changes in TSI-Measurement Values



Researchers Need a Composite Record

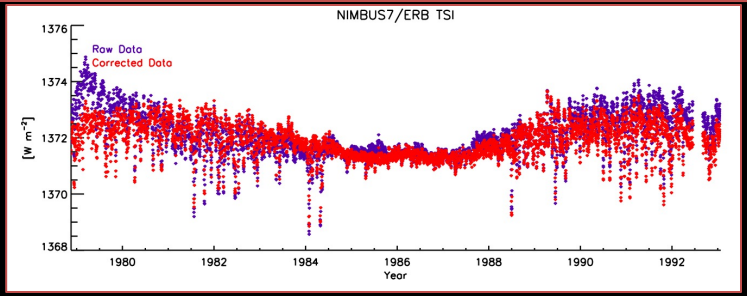


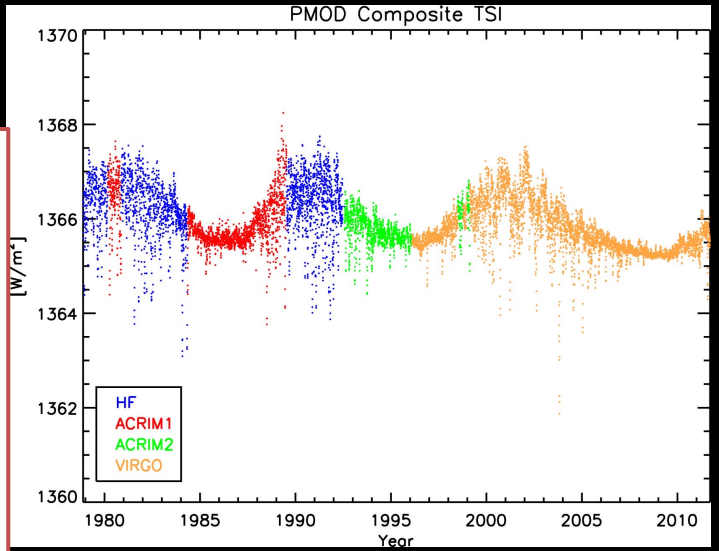
Traditional TSI Composites

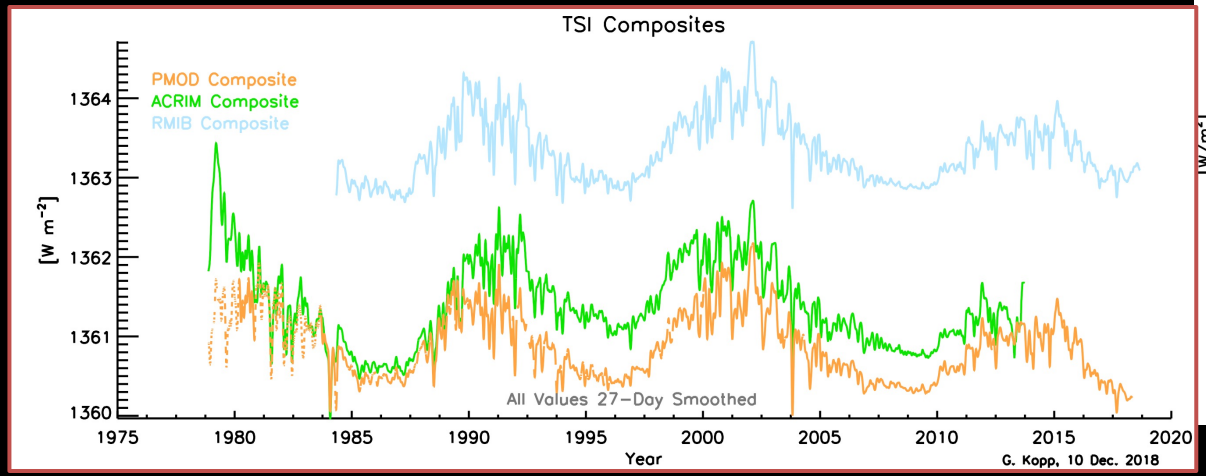


Issues with Traditional Composites

- Created by individuals (PIs)
- Binary (and biased) selection of instrument data used
  - Discontinuities at boundaries
- Controversial corrections applied to data records
- Normalizations incorrect
- Lack uncertainties







ISSI Team Laid Groundwork

1. Agreed upon the absolute value to use for the composite TSI record
2. Agreed upon an unbiased computational methodology to create this new composite

Team: Greg Kopp (PI), Will Ball, Steven Dewitte, Thierry Dudok de Wit, André Fehlmann, Wolfgang Finsterle, Claus Fröhlich, Sabri Mekaoui, Werner Schmutz, Richard Willson, Pia Zacharias

Solar Irradiance Science Team (SIST) Effort

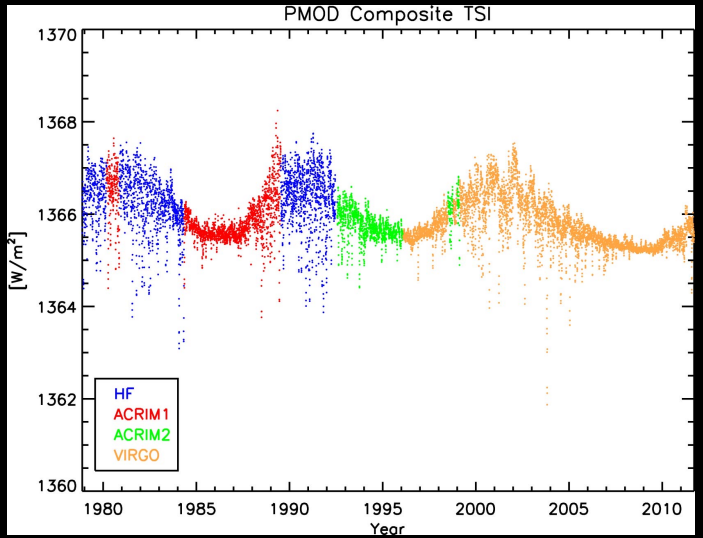
1. Demonstrate, implement, and improve the computational methodology to create a new community-consensus TSI composite including time-dependent uncertainties with (partial) continued involvement from ISSI team
2. Distribute the composite to public and produce a publication detailing the methodology
3. Establish a system to update this TSI composite regularly as new data are available

Collaborator	Expertise & Responsibility
Dr. Will Ball	Modeler for the SATIRE TSI proxy model. Comparisons to this model provide insight into individual data record accuracies and realism of resulting composite.
Dr. Thierry Dudok de Wit	Scientist and mathematician with expertise in statistical analyses methods, PCA, and Bayesian techniques applied to creating composite records. Dr. Dudok de Wit has demonstrated a proof-of-concept TSI composite using the described and agreed upon methodology. He will help tune the Bayesian approach during the initial, more experimental, stages of the proposed effort.
Dr. Wolfgang Finsterle	Instrument Scientist for Picard/PREMOS provides updated PREMOS TSI data and knowledge about that instrument's uncertainties due to on-orbit operations influences
Dr. Claus Fröhlich	PI for SoHO/VIRGO who is responsible for VIRGO TSI and creation of PMOD TSI composite. Dr. Fröhlich provides knowledge not only about the VIRGO but also the oldest TSI instrument, the NIMBUS-7/ERB. He also shares his experience from having created the most prominent TSI composite, that of PMOD.
Dr. Werner Schmutz	PI for Picard/PREMOS provides the absolute value of the PREMOS TSI measurements and insight into the World Radiometric Reference maintained by his organization at PMOD
Dr. Richard Willson	PI for ACRIM-1, -2, and -3, spanning 30 years of TSI measurements. Dr. Willson has knowledge of the older TSI instruments including the NIMBUS-7/ERB as well as experience in creating the ACRIM TSI composite

Summary: *Provide data users with a single TSI composite including, for the first time, time-dependent uncertainties, a non-binary selection of contributing instruments, and an unbiased weighting of those instruments*

Desired Improvements in Community-Consensus TSI Composite

- Include recent improvements to *absolute accuracy* in the newer TSI measurements
  - SORCE, PREMOS, TCTE, and TSIS-1 help transfer improved ground-based calibrations to space
- Weight data from *all available instruments*
- Use *unbiased statistically-driven approach* rather than favored instrument
- Include *time-dependent uncertainties* to indicate temporal regions where contributing data may be suspect
- Smooth transitions and gaps scale-wise
- Have community involvement



Method for Creating Composite

- Estimate noise for each instrument based on high-frequency daily values
  - Predictive-model noise-estimating method agrees well with independent results from Kopp, *SWSC*, 2014
- Extrapolate based on 1/*f* noise model
- Apply wavelet transform for scale-wise analysis
- Compute weighted average of all instrument data scale-wise based on frequency-dependent noise model
  - Surrounding values smooth gaps and discontinuities scale-wise
- Invert net wavelet transform
- Estimate uncertainties
  - Monte Carlo of 1/*f* noise model

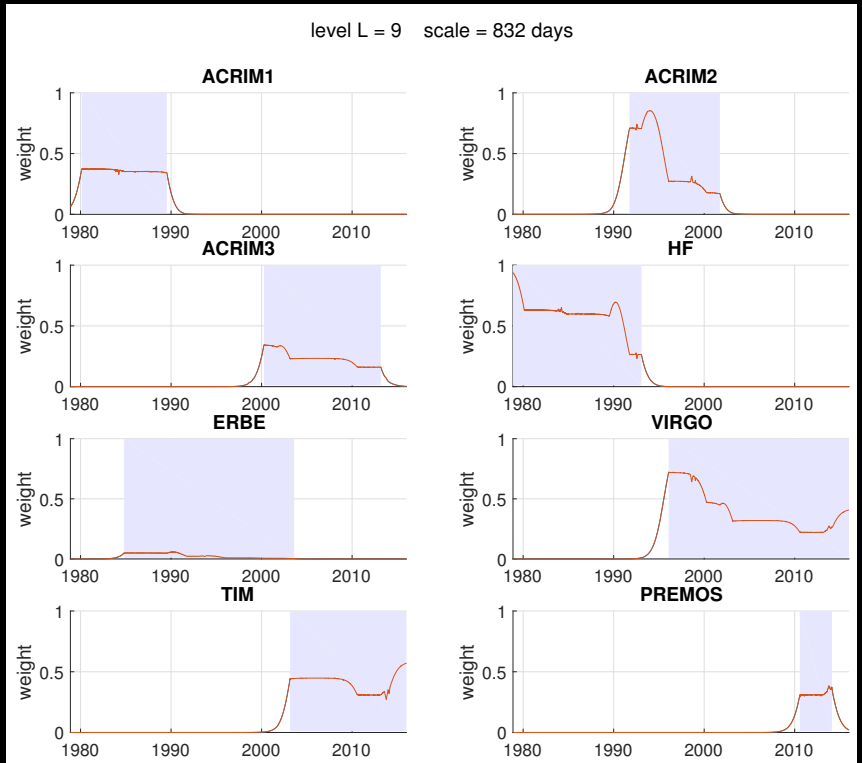
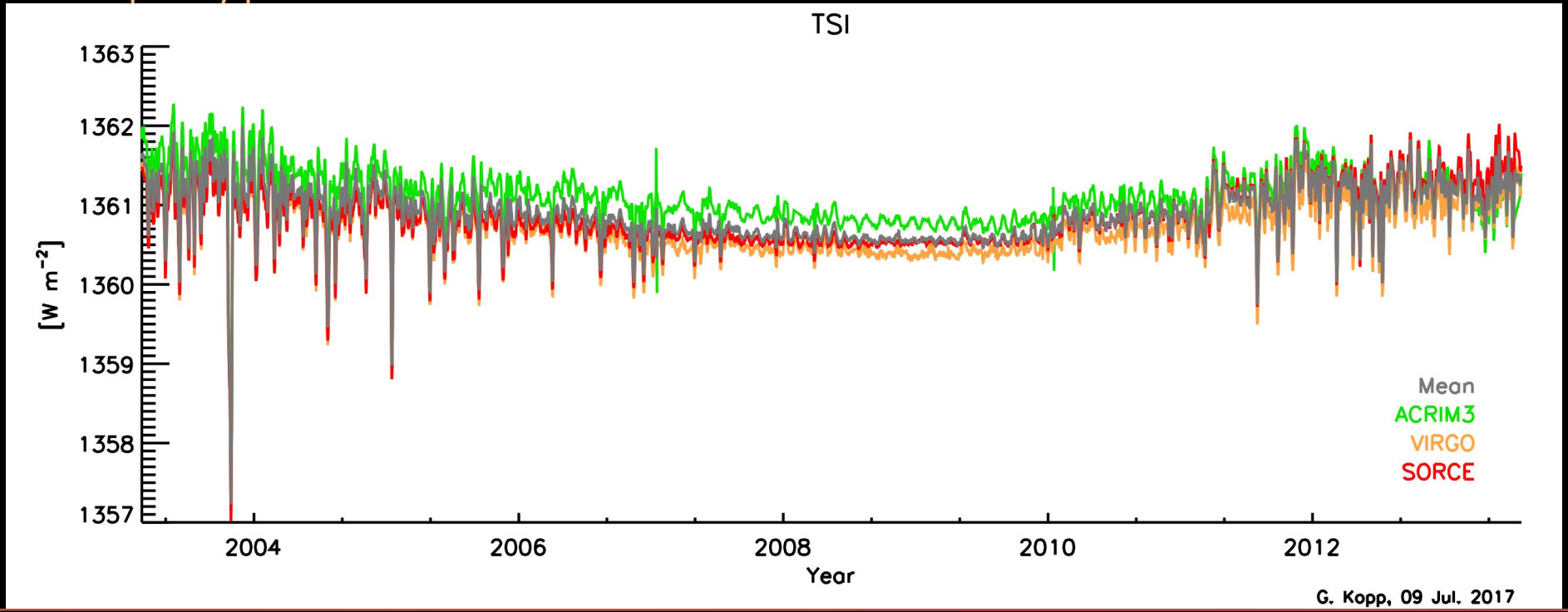


Figure 6. Time-dependent weight determined from each instrument for a characteristic scale of 832 days (Level 9 of the wavelet transform). The shaded area represents the time interval during which the instrument was operating.

Dudok de Wit *et al.*, *GRL*, 2017

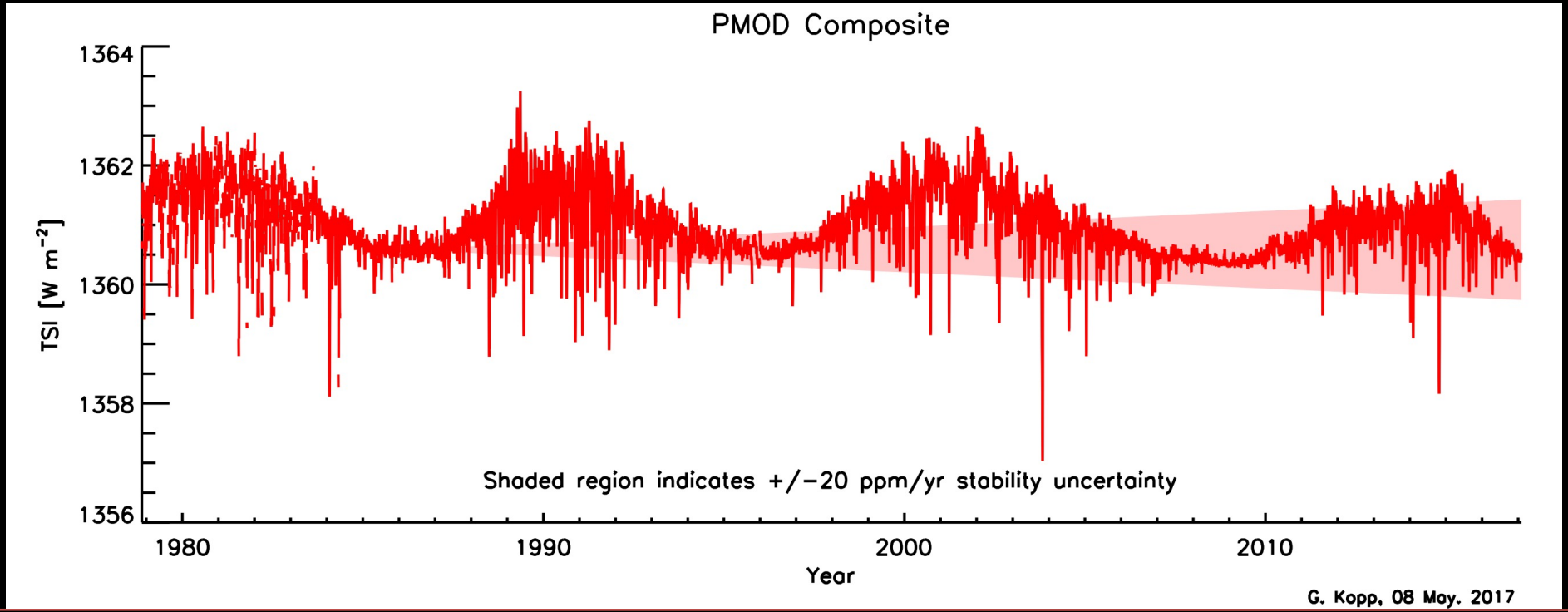
Measurement Differences Show 1/f Power Scaling

- Dispersion is not indicative of linear trends or of white noise
- Use as noise model of each instrument for scale-dependent weightings based on high-frequency predictive-model correlations

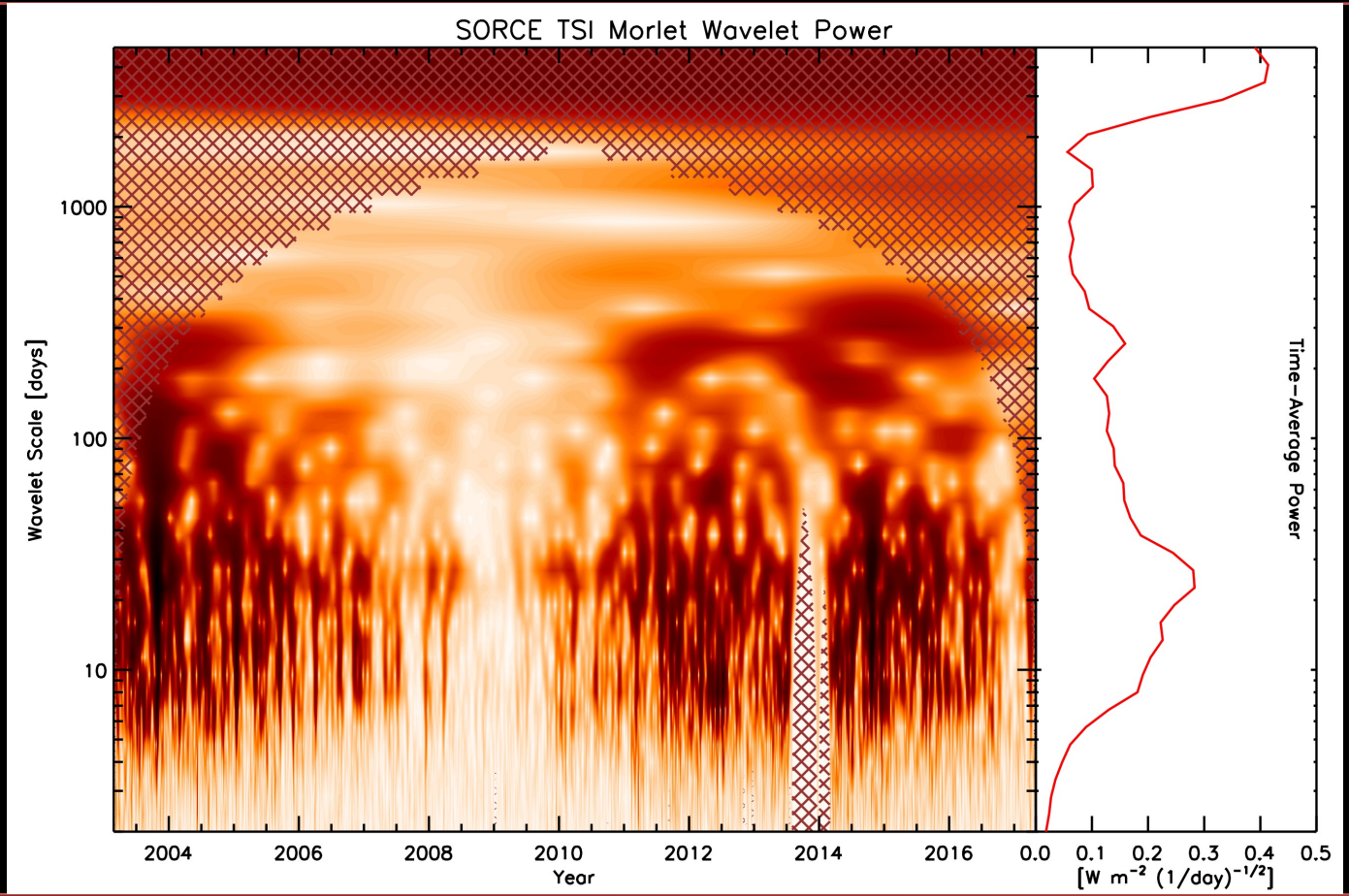


Wedge Trends in Differences Are Misleading

- Linear trends in instrument differences are not what is observed
- Linearly-increasing uncertainties overestimate actual uncertainties in time (eventually)



Wavelet Analyses Determine Temporal Regions of Influence



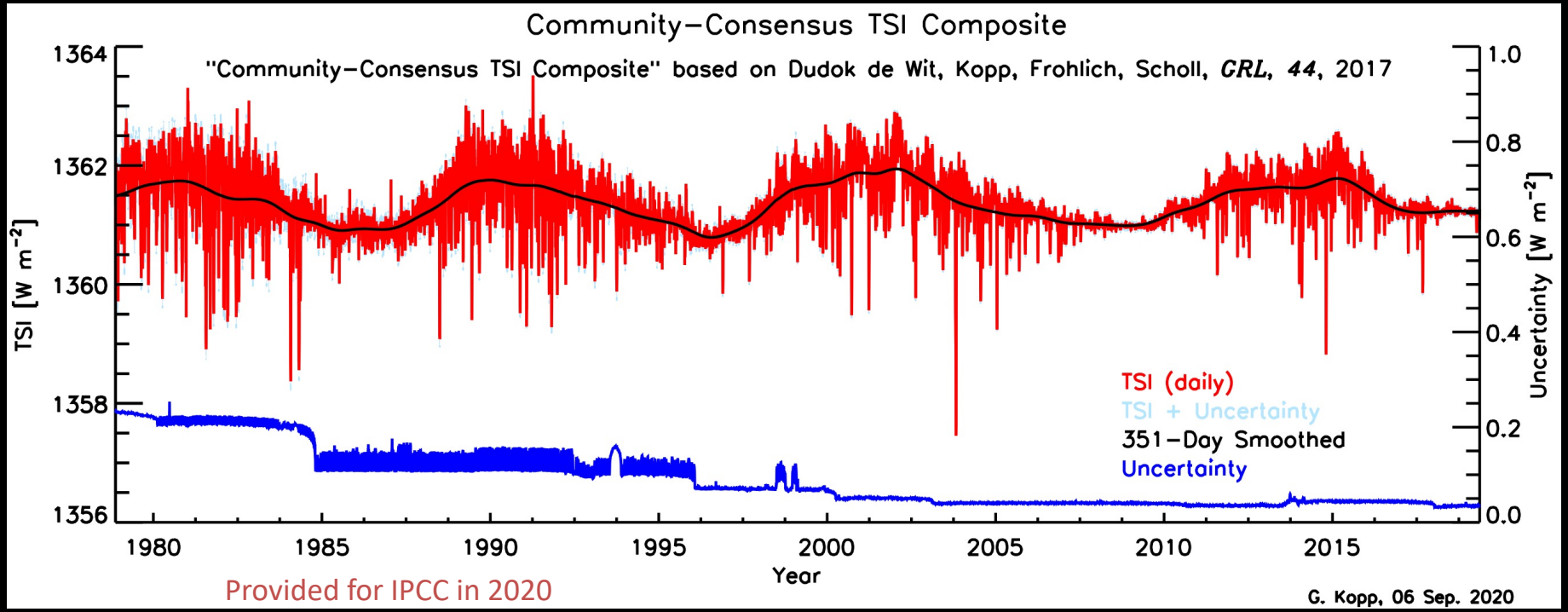
Method for Creating Composite

- Fill data gaps using expectation-maximization
  - Gap-filled values are not used in final result
- Estimate high-frequency uncertainties for each data set
  - Use nearest-neighbor approach
- Allow for frequency-dependent uncertainties
  - 1/*f* scaling applied
- Use wavelet analysis of each data set for multi-scale decomposition
- Combine wavelets at each scale using weighted average to get wavelet of composite
- Invert wavelet to obtain composite
- Estimate uncertainties via Monte Carlo based on noise model

The Community-Consensus TSI Composite

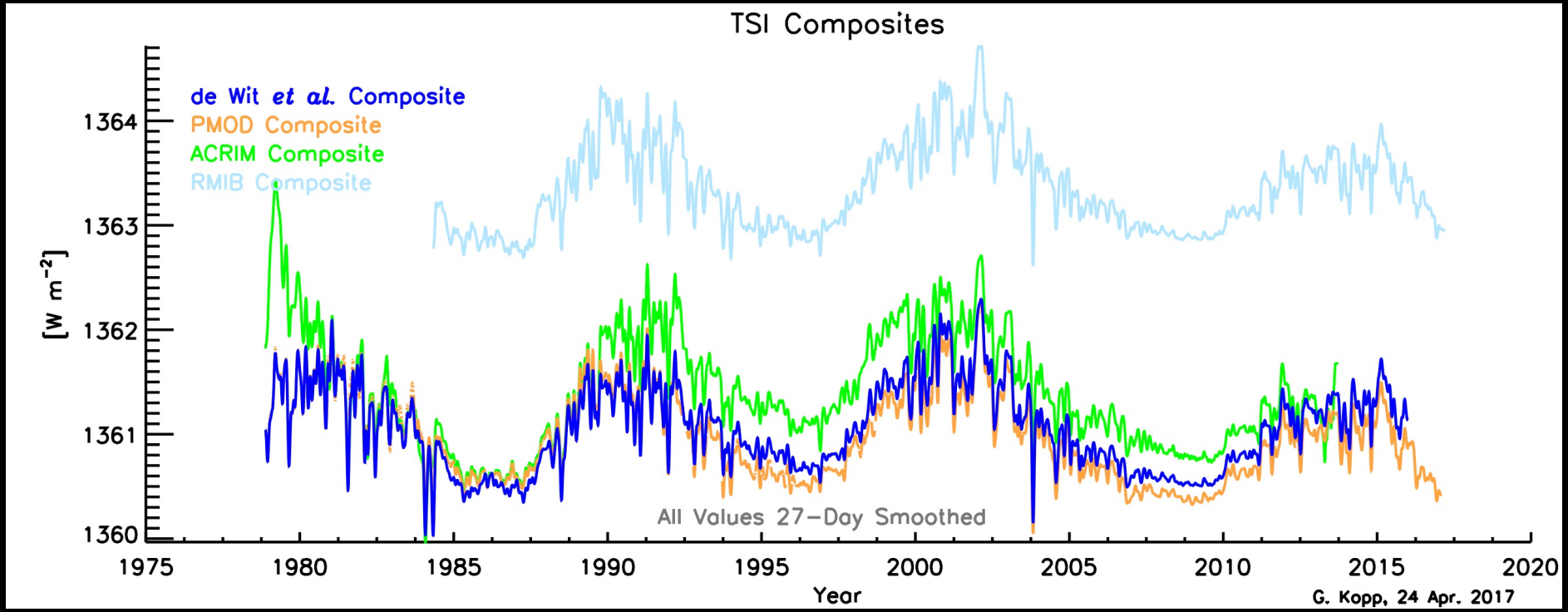
- TSI composite improved with reduced biases and better instrument-transition overlaps

TSI instrument and composite data are available at:
http://spot.colorado.edu/~koppg/TSI



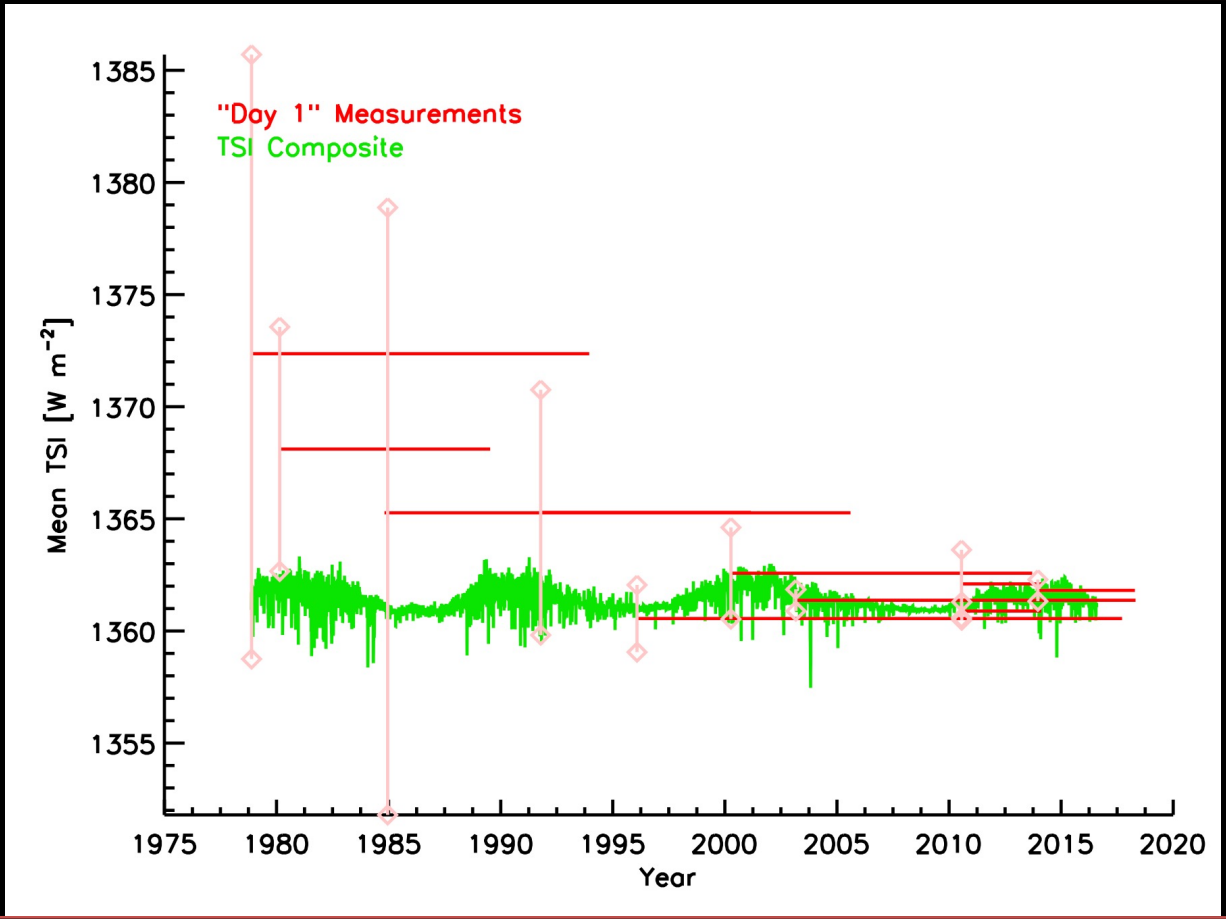
Provided for IPCC in 2020

Community-Consensus TSI Composite

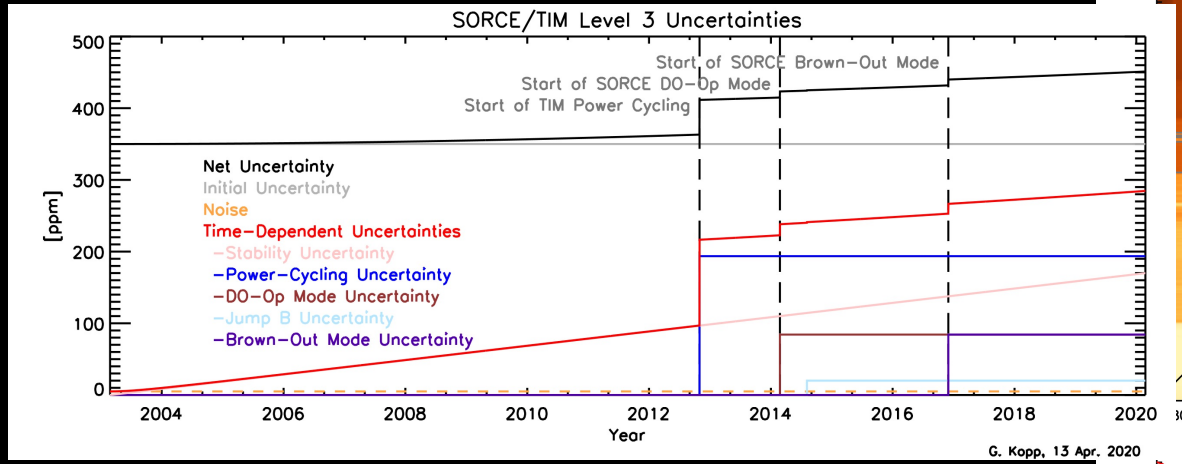


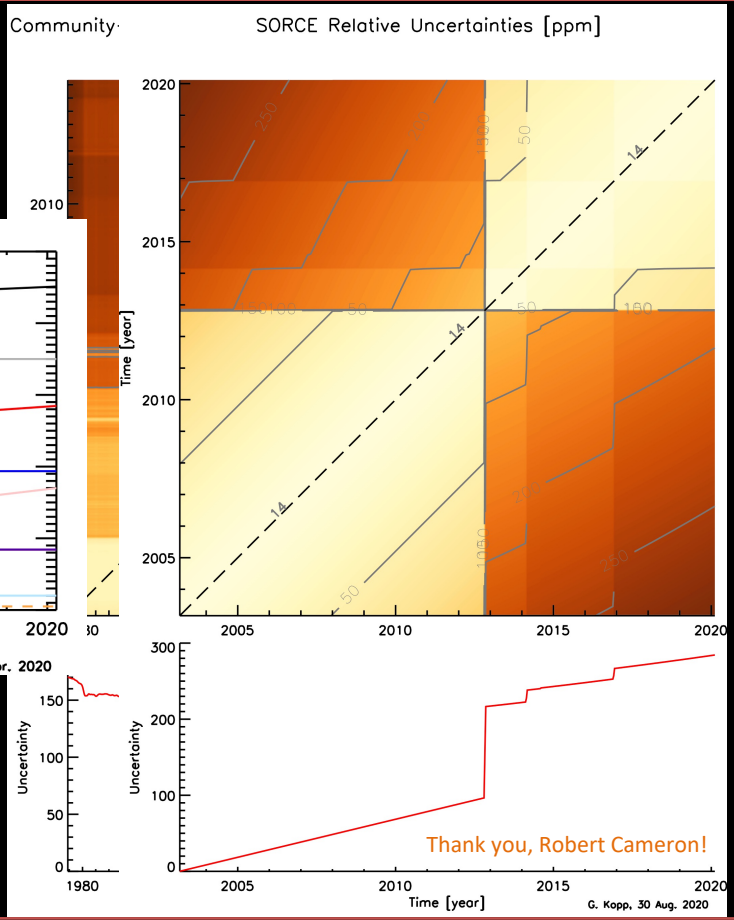
Includes efforts of former ISSI team and SIST-1 team

And What About the Absolute Value?



Relative Uncertainties Between Times Need to Be Expressed in 2D





Community-Consensus TSI Composite – Summary

- TSI-community based for openness
- Uses all available instrument data
- Scale-wise weightings smoothly fill gaps
- Uses an unbiased statistical approach
- Normalized to most accurate instruments
- Has time-dependent uncertainties

TSI instrument and composite data are available at:
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